MINERALOGY AND CRYSTALLOGRAPHY OF COMET 81P/WILD 2 PARTICLES.

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Introduction: The Stardust spacecraft collected coma grains from Comet 81P/Wild 2 on Jan. 2004 [e.g., 1]. After the 2-year return journey to the earth, the sample return capsule was successfully recovered in the desert of Utah on Jan. 15, 2006. Because comets are believed to be the most primitive bodies in the solar system, direct analysis of cometary material should offer substantial information to understand the formation of the solar system. As a part of preliminary examination (PE) [2,3], we performed mineralogical and crystallographic study on Comet Wild 2 particles, which proved to show different mineralogies from one sample to another. We report here the mineralogy and crystallography of some particular particles.

Samples and Analytical Methods: The Stardust samples were provided as three different forms (Table 1). All the samples were analyzed by FEG-SEM (Hitachi S-4500 with EDS and EBSD) for characterizing the constituent phases. TEM (JEOL JEM2010 with EDS) was used for analyzing ultra thin sections on TEM grids. Some particles were mounted on 1"-diameter rounded glass slides and analyzed by single crystal X-ray diffraction using synchrotron radiation (SR) at BL47XU, SPring-8, Japan. The beam size was less than 1 micron on the samples.

Results: The size of studied particles ranged from <1 to 10 microns. Most particles are composed of amorphous silica with scattered tiny spherules of Fe(+Ni) sulfide and Fe-Ni metal (~100 nm) (Fig. 1). Fe sulfide is usually dominant over Fe-Ni metal. These particles also contain abundant vesicles, suggesting melting with aerogel during the capture process.

Several particles contain crystalline silicates. Major crystalline phases are olivine and pyroxene (Fig. 2). These crystals are usually less than 1 micron in diameter. The chemical compositions of both olivine and pyroxene show wide ranges (mg#=0.6-1) even in the same particle, as described in [3,4]. SEM-EBSD analysis identified augite in one ultramicrotomed slice.

Among the samples studied, some unusual phases were found. CF12,0,16,3,0 contains a ~1.5x2.5 microns grain whose composition is close to K-feldspar. We tried EBSD analysis, but no diffraction was obtained. CF6,0,10,7,23 is a unique particle that contains several different phases. Olivine and pyroxene, whose composition is variable (mg#=0.70-0.95), dominate in this particle. There is also possible Mg-Fe carbonate (breunerite) in this particle. This carbonate occurs as a cluster measuring ~200x300 nm associated with amorphous silica (Fig. 3). EDS analysis suggests that it is a mixture of Mg-Fe carbonate, amorphous silica and Fe sulfide. No Ca was detected. The SAED pattern of this cluster shows powder diffraction (with some sharp spots) generally consistent with magnesite. This diffuse ring pattern suggests that the grain size of carbonates is small. Mg-rich chromite is also present in this particle, associated with amorphous silica and Fe sulfide (Fig. 4).

Among 6 particles analyzed by SR-XRD, only 1 sample was crystalline. The obtained diffraction image of C2126,2,68,1,0 shows sharp spots from multiple domains (Fig. 5). We analyzed several different areas on this particle, and found that same diffraction spots were observed even if the sample was moved in a few microns, suggesting the presence of >1 micron size crystals. Because SEM-EDS analysis shows abundant Si and O, we tried several silica phases to index the obtained diffraction patterns and found that tridymite and cristobalite matched the observed ones.

Discussion and Conclusions: Comet Wild 2 nucleus samples studied here contain several different phases. Except for amorphous silica contaminated with aerogel, submicron olivine and pyroxene with variable composition are major phases. We also found Mg-Fe carbonate, Mg-rich chromite, and silica. The presence of carbonate is especially important. Because it is associated with amorphous silica and Fe sulfide, it could be indigenous to Comet Wild 2. If this is the case, this is the first discovery of carbonate in Comet Wild 2, and thus shows evidence for aqueous alteration. Mg-Fe carbonate is reported from hydrous IDPs [5,6], but the occurrence and size are different. We have not found phyllosilicates associated with Wild 2 carbonate although they are closely associated in hydrous IDPs [5,6]. Furthermore, many other PE studies (including other particles in this study) show that Comet Wild 2 particles are most similar to anhydrous IDPs [3]. Because contamination should be carefully considered, we are further characterizing this carbonate-bearing particle to conclude whether it is contamination or truly an exotic component of Comet Wild 2. The presence of tridymite and cristobalite is also unique. Because they are from a terminal particle, the chance of contamination may be low.

References: [1] Brownlee D. E. et al. (2004) *Science*, 304, 1764-1769. [2] Brownlee D. E. et al. (2006) *Science*, 314, 1711-1716. [3] Zolensky M. E. et al. (2006) *Science*, 314, 1735-1739. [4] Zolensky M. E. et al. (2007) *LPS XXXVIII*. [5] Tomeoka K. and Buseck P. R. (1986) *Nature*, 231, 1544-1546. [6] Germani M. S. et al. (1990) *EPSL*, 101, 162-179.

Table 1. List of the Stardust samples analyzed in this study.

Sample number	Facility*	Form
CF3, 0, 2, 1, 0	UT	Potted butt
CF12, 0, 16, 3, 0	UT	Potted butt
CF3, 0, 2, 1, 15	UT	TEM grid
C2027, 2, 69, 1, 6	UT	TEM grid
C2054, 0, 35, 52, 5	UT	TEM grid
CF6, 0, 10, 7, 15	UT	TEM grid
CF6, 0, 10, 7, 23	UT	TEM grid
C2027, 2, 69, 4, 0	SP8, UT	On 1"ϕ glass slide
C2027, 2, 69, 5, 0	SP8, UT	On 1"ϕ glass slide
C2027, 2, 69, 6, 0	SP8, UT	On 1"ϕ glass slide
C2027, 3, 32, 2, 0	SP8, UT	On 1"ϕ glass slide
C2126, 2, 68, 1, 0	SP8, UT	On 1"ϕ glass slide
C2126, 2, 68, 3, 0	SP8, UT	On 1"ϕ glass slide

*UT: University of Tokyo, SP8: SPring-8.

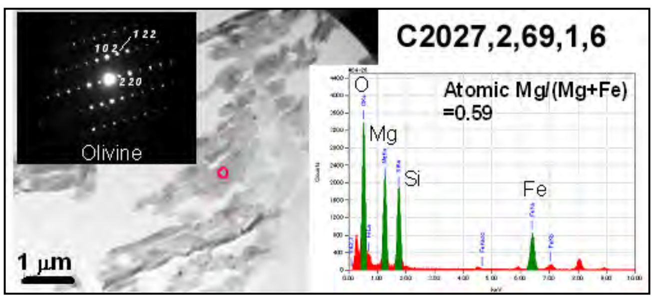

Fig. 2. Olivine in C2027,2,69,1,6. This olivine is very Fe-rich (Fo_{59}) as shown in EDS.

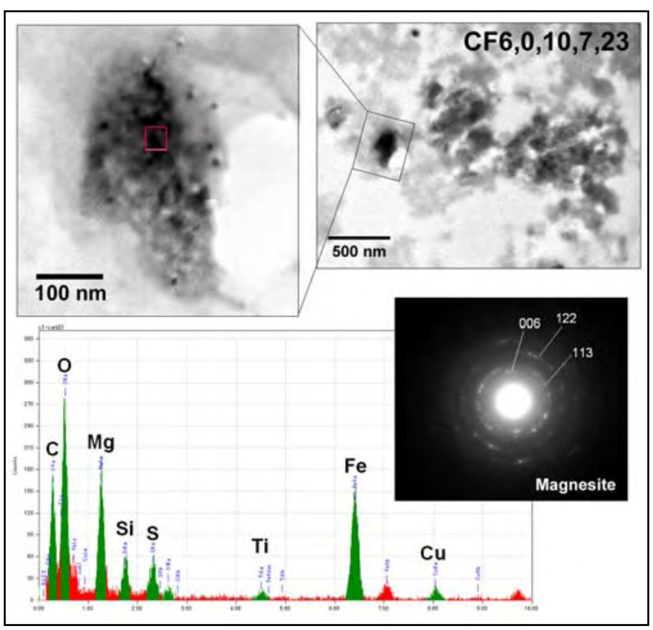

Fig. 3 (Left). Possible Mg-Fe carbonate (Ca-free) in CF6,0,10,7,23. EDS shows the presence of amorphous silica and Fe sulfide associated with Mg-Fe carbonate.

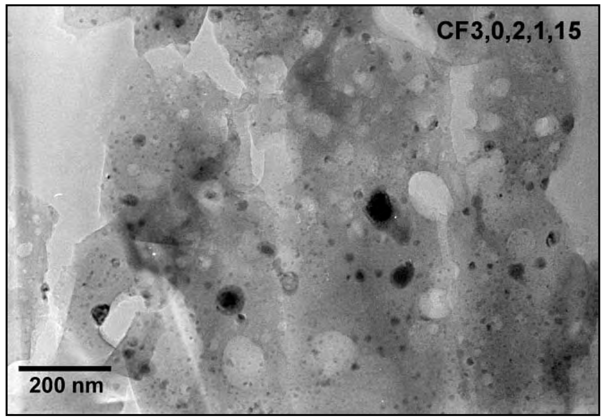

Fig. 1. Typical texture of amorphous silica with scattered Fe sulfide and Fe metal (dark spherules). Abundant vesicles (~100 nm in diameter) are also present.

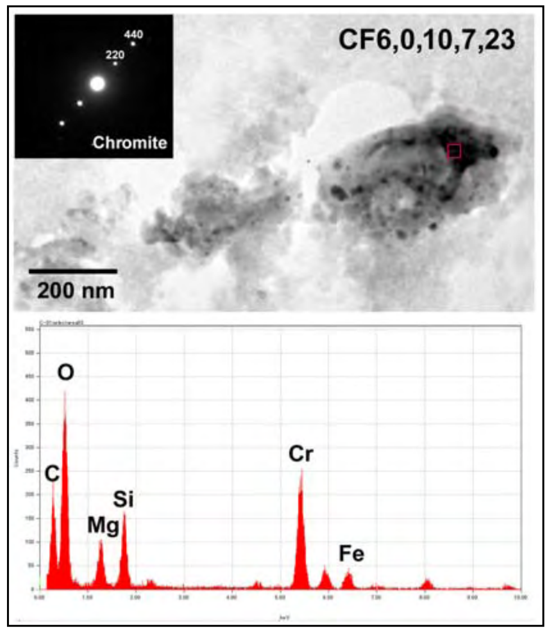

Fig. 4. Mg-rich chromite in CF6,0,10,7,23 (dark areas in TEM image). They are associated with amorphous silica and Fe sulfide.

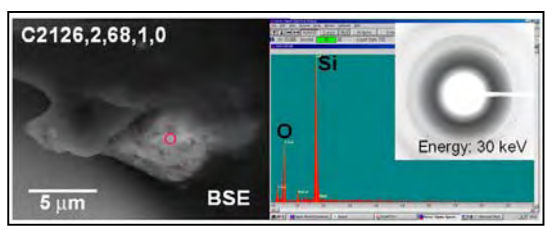

Fig. 5 (Above). BSE image of silica in the terminal particle C2126,2,68,1,0 (above left). SR-XRD (above right) shows diffraction from multiple phases that could be indexed by tridymite and cristobalite.